

Enhancing Qualitative Medical Research through Epistemic Network Analysis:

A Study of Emotional and Social Dimensions in Healthcare Settings

Dr. J. Walker¹, Dr. C. García², Dr. Y. Kim^{3*}

¹ School of Medicine, University of Edinburgh, Edinburgh, United Kingdom

² Department of Epidemiology, University of Barcelona, Barcelona, Spain

³ Division of Medical Informatics, Seoul National University, Seoul, South Korea

Abstract: Contemporary educational research has increasingly pointed to socioemotional dimensions of learning as important in promoting academic progress and sociocognitive developments. Epistemic Network Analysis, a methodology for producing quantitative ethnographies based on complex learning environments, has only begun to examine socioemotional facets of learning in classrooms. The aim of this research is to investigate what and how Epistemic Network Analysis can contribute to qualitative, socioemotionally-focused ethnographies of classroom learning communities. To do this, we employed Epistemic Network Analysis to analyze data collected during a semester of studies, in parallel to a stage developmental analysis of the same community using qualitative methods. The results of this study specifically show the importance of prior experience and how this interacts with participants' connectedness to the community, as well as how group dynamics are a vital aspect of community discourse and that the socioemotional dimensions that people attach to it may be the determinants of stage advancement. More generally, this study shows how Epistemic Network Analysis can be used to better understand complex socioemotional phenomena in learning communities by combining it with deep, qualitative ethnographies.

Keywords

Cooperative/collaborative learning; Data science applications in education; Learning communities; Pedagogical issues; Post-secondary education

1. Introduction

The aim of this article is to elucidate how digital technologies can be used to understand and support socioemotional dimensions of learning in classroom learning communities. This is a vital area of development and a “future theme” in the growing field of learning analytics, having examined emotions from a variety of methods though still lacking situated accounts in the sociocultural contexts in which they occur (D’Mello, 2017, p. 122). Specifically, we are interested in the unique potential of the quantitative ethnographic approach of Epistemic Network Analysis (Shaffer, 2017; 2018) to inform, and be informed by, thick descriptions of learning in classroom learning communities. Mixed ethnographic approaches such as this have the potential to address complex, situated emotional phenomena, yet the one published ENA study that touches on

emotions is not set in an educational context (Frey et al., 2019), and others remain exploratory (e.g., Authors, 2019). This article cuts across the three important areas of computers and education – classroom learning communities, emotions, and learning analytics – in an attempt to address a “grand research challenge” facing the field.

1.1 Classroom Learning communities

The notion of ‘learning communities’ has been one of the most important developments in education over the past several decades (Authors, 2018b; Matthews, Smith, & MacGregor, 2012), particularly as learning-how-to-learn and collaborative learning competencies have become increasingly required in the innovation age (Collins, 2017). Despite the wide variety of contexts in which the learning community approach has proliferated, such as in classrooms (Bielaczyc, Kapur, & Collins, 2013), organizations (Tosey & Marshall, 2017) or higher education (Tinto, 2000), the learning sciences have uniquely defined learning communities from sociocultural perspectives (Lave & Wenger, 1991; Rogoff, 1994). Specifically, they describe learning communities as having a “culture of learning, in which everyone is involved in a collective effort of understanding” (Bielaczyc & Collins, 1999, p. 269). Often conceptualized as knowledge building communities (KBCs: Scardamalia & Bereiter, 2014), in these approaches, students’ ideas are put at the center of activity. The aim of the community becomes advancing their knowledge while taking collective cognitive responsibility to do so (Zhang, Scardamalia, Reeve & Messina, 2009). Although significant efforts to support the cognitive aspects of collaborative learning have been developed (Miyake & Kirschner, 2014), such as with the designs for social infrastructure (Bielaczyc, 2009) and mutually shared cognition (Järvelä, et al., 2016), research on learning communities has generally stayed in sociocognitive realms and stayed away from dealing with socioemotional dimensions of learning (Järvenoja & Järvelä, 2013).

1.2 Studying emotional dimensions of learning communities using stage models

In recent years, increasing attention has been paid to socioemotional aspects of learning across the learning sciences and computer-supported collaborative learning (Cress, Rosé, Law, Ludvigsen, 2019). Baker, Anderson, and Järvelä (2014) discussed the importance of considering emotions as deeply tied and inseparable from cognition, already evident in the sociocultural writings of Vygotsky (1978). These issues are vital to explore because, in practice, simply asking students to learn together – even if they are highly cognitively functioning – does not guarantee a successful outcome (Barron, 2003). Naykki, Järvelä, Kirschner and Jarvenoja’s (2014) research on socioemotional regulation showed how interpersonal challenges and conflicts can be detrimental for effective collaboration. Overall, research has shown that working through the complex socioemotional issues often involved in intensive collaboration can have impressive intrapersonal, interpersonal (Weissberg, Durlak, Domitrovich, & Gullotta, 2015), and sociocognitive benefits (Zins, Bloodworth, Weissberg, & Walberg, 2007).

One important body of knowledge to address socioemotional issues in classrooms organized as learning communities comes from research on groups, which has been exploring the role of emotions in social functioning for over a half-century, beginning with Lewin (1952) and Bion (1959). For example, many studies have explored the emotions of groups as they develop, such as in identifying the conflict stage of group development, which is characterized by intragroup tension and confrontation (Arrow, Poole, Henry, Wheelan, & Moreland, 2004; Corey, Corey & Corey, 2018). A growing number of studies on classroom learning communities have applied stage models of group development to examine their socioemotional dynamics and overall growth, as

these two concepts generally refer to collections of participants that range from about 15-30 members (Authors, 2015; Carabajal, LaPointe, & Gunawardena, 2003; McInnerney & Roberts, 2004).

Tuckman's stage model, one of the most commonly applied theories of group development (Brabender, 2010), asserts that groups generally develop through the five stages called forming, storming, norming, performing, and adjourning (Tuckman & Jensen, 1977; Miller, 2003). While groups may regress at times, show signs of multiple stages simultaneously, advance discontinuously, or even be viewed as advancing through phases instead of stages, Tuckman's model is a useful way to examine group (and classroom learning community) developmental phenomena from a socioemotional lens (Arrow et al., 2004).

Modern perspectives on group development have narrowed down Tuckman's stages to the initial, transition, working, and final stages (Corey et al., 2018). The initial stage is characterized by an excitement towards a new beginning, and a general focus on getting acquainted, which often is expressed in shallow, but polite social expressions. Risk taking during the initial stage occurs at low levels, as the participants explore their social environment tentatively (Arrow et al., 2004). There are often moments of awkwardness or participants looking for direction.

The transition stage follows the initial stage. During this stage, participants weigh their engagement in the group on a range between playing it safe and risking to get more involved. Control and power issues can emerge between participants, which is often the basis of interpersonal conflicts. The moderator(s) is not immune from this conflict, and is often the subject of tests by the participants to see how much they can be trusted (Corey et al., 2018; Tuckman & Jensen, 1977).

Successful groups – those that are able to move past the tension and mistrust characterizing the transition stage – enter into the working stage. During this stage, an openness between participants takes hold on the basis of trust and cohesion. Participants take more risks as they increasingly disclose personal information about themselves. While conflicts may occur, these are handled respectfully, with feedback given with a true intent to help and out of care for the personal growth of peers. The beneficiaries of this feedback accept feedback non-defensively, feeling supported so they can make changes (Corey et al., 2018; Tuckman & Jensen, 1977).

Lastly, in groups that terminate (as opposed to ones that are structured with rotational membership), the final stage is characterized by sadness or anxiety about the separation, with fears and hopes about the future frequently expressed. This stage is often accompanied by a lowering of intensity as participants become reflective or even evaluative about their experiences. Talk is often focused on maintaining the group, such as by organizing follow up meetings or using digital tools (e.g., Facebook group) to stay connected. Oftentimes the most important material comes out during this stage, as members realize that their time together is limited (Brabender, 2010; Tuckman & Jensen, 1977).

1.3 Using ENA to Explore Socioemotional Dimensions

Epistemic Network Analysis (ENA) is a quantitative ethnographic technique to create computer-based models that show the structure of connections between collaborating individuals in relevant aspects of their discourse (Swiecki & Shaffer, 2020). While it has rarely been applied to socioemotional dimensions of learning (e.g., Frey et al., 2019), ENA is grounded in sociocultural theory that views learning as interconnected in a broader ecology and therefore can be applied to such rich contexts (Shaffer, 2018).

Based on its sociocultural framing, ENA assumes that meaningful features of data can be identified, that these data are structured locally, and that the way the meaningful features are connected to one another is important (Shaffer, 2017; Shaffer, Collier, & Ruis, 2016; Shaffer & Ruis, 2017). For example, if an inquiry group is studying a particular topic, they talk about important features such as their goals, how and when they can work together, what questions interest them, and so on. They have a series of conversations during their activities, and a key part of understanding their inquiry process is modeling how they think about the relationships between the different facets of their inquiry. ENA models the connections between these features by quantifying their co-occurrence within conversations, producing a weighted network of co-occurrences, along with visualizations that are associated with each unit of analysis in the data. ENA analyzes all of these networks simultaneously, resulting in a set of networks that can be compared both visually and statistically (Shaffer, 2018).

This research seeks to leverage the potential of applying ENA to extend thick descriptions of socioemotional dimensions of learning in classroom communities. Specifically, we applied ENA to an existing qualitative analysis of a classroom learning community that examined socioemotional dimensions of learning using a group developmental framework (Authors, 2020). The aim of the current study is to investigate what ENA can tell us about the way socioemotional dimensions of learning are expressed in learning communities in relation to stages of group development.

2. Methods

Achieving the aim of this paper involved (a) testing the relation between a qualitative analysis and ENA to see if they yielded consistent results; and (b) seeing how this could elucidate unexpected aspects of the qualitative ethnography used to determine socioemotional expressions and stages of group development. We describe the research setting in section 2.1 before elaborating on the specific techniques used to answer our research questions in the subsections of 2.2.

2.1 Research setting, participants, and course design

The setting of this research took place in an intensive, 13-week graduate course on the topic of learning communities taught within the Department of Instruction, Learning, and Teacher Education at the University of Haifa, during the Fall 2017-2018 semester. Eighteen students from heterogeneous backgrounds enrolled in the course. Ethnically, the students included 10 Jewish, three Christians, three Druze, and two Muslims. The age range was from 24 to 46. Three of the participants were male, and 15 were female. Ten of the students were professional educators in K-12 contexts, ranging from normative education, special education, and education for the gifted. Three of the students were in a process of career changes to education from the life sciences, business administration, and nursing, respectively. The remaining students worked in educationally related professions outside the formal system. Sixteen of the students had studied together as a cohort during the previous year, and were now starting their second year together in a two-year program. Two students from another program that had closed joined the course as well and had no prior interaction with the main cohort. An instructor and teachers' assistant – which we refer to as moderator and co-moderator due to their unique facilitative roles – led the course.

The course was designed as a Humanistic Knowledge Building Community (HKBC: Authors, 2018a), which integrated idea-centered activities of KBCs (Scardamalia & Bereiter, 2014) with person-centered activities rooted in humanistically-oriented encounter group designs (Cornelius-White & Harbaugh, 2010; Rogers, 1970). The general structure included a weekly four-

hour face-to-face meeting and continued activity online using the Knowledge Forum for the remainder of the week (Figure 1). The knowledge building activities were designed based on principles of knowledge building (Chen & Hong, 2016; Scardamalia, 2002; Zhang, Hong, Scardamalia, Teo, & Morley, 2011). After students were introduced to the theory of knowledge building at the start of the course, the students were asked to formulate collective wondering areas (Zhang, Tao, Chen, Sun, Judson, & Naqvi, 2018) based on the topics about learning communities that they wanted to study, take epistemic agency by arranging them into inquiry threads, then research them in small, interacting groups for the remainder of the semester (Zhang et al., 2009). Weekly face-to-face activities were varied, but included jigsaw activities, opportunities for independent and small group work, and presentation and feedback sessions. For the most part, students were given opportunities to continue researching their topics during the week, building on the existing community knowledge base in the different wondering areas using scaffolds to support new theories or information, alternative explanations, and asking questions about incomplete ideas. Participants were also challenged to rise-above existing ideas by formulating them into increasingly higher levels (Zhang et al., 2011).

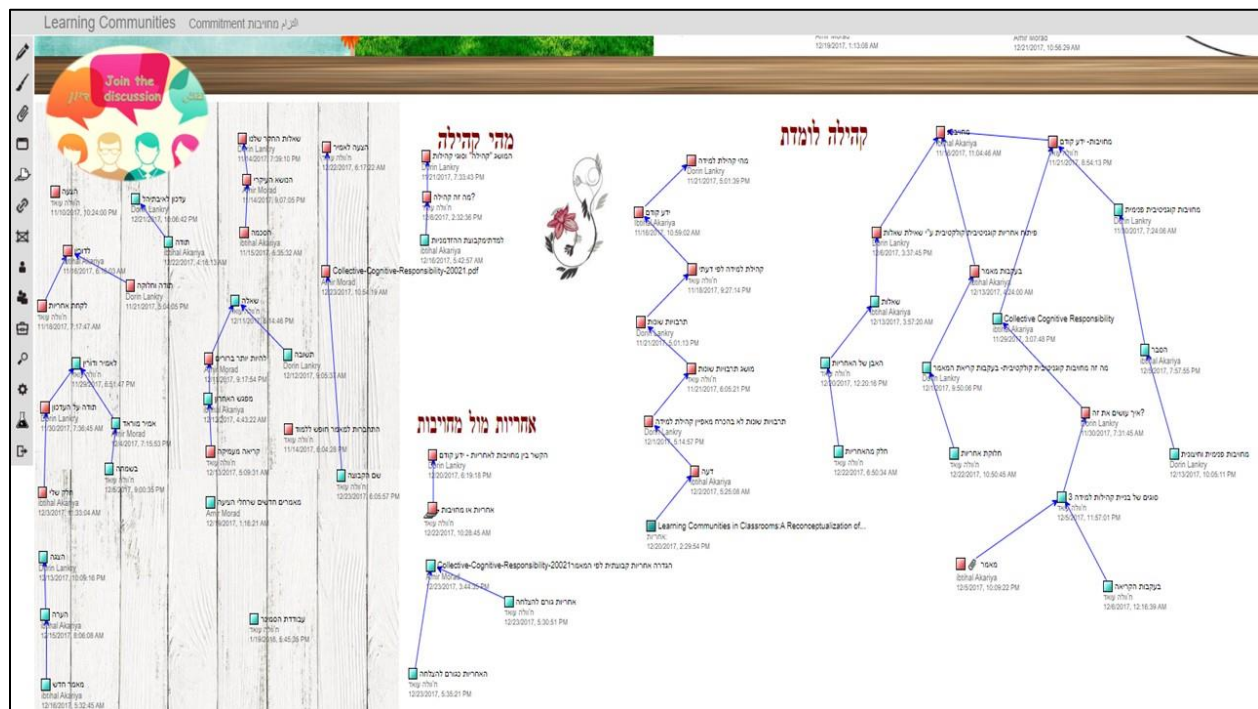


Figure 1. Chains showing advancing knowledge on the Knowledge Forum

Person-centered activities supplemented the knowledge building activities based on the rationale that idea-advancement can be promoted by helping the students reflect on their identities as knowledge builders. While identities are a broad concept that can include many aspects of a person's life, in this context it was focused on the way participants collaborated with other members in the community in addition to continually refining their research interests in the community as they related to their personal goals (Authors, 2018a). At the start of every week, a person-centered activity was designed to foster this type of individual and collective discourse. For example, during the first week the students were asked to draw a picture of themselves in the current moment and at the end of the semester, then show and describe their drawings to the

community. In doing so, the students revealed a lot about their identities as knowledge builders (e.g., as a competitive student or as somehow who likes to listen) and these were continually returned to and deepened as the semester continued. As the participants shared knowledge building experiences and got to know each other better throughout the semester, they could then give each other feedback about their identities as knowledge builders to improve their individual and collective practices.

To continue the person-centered reflective discussions online, we repurposed a section of the Knowledge Forum to focus on students' identities. In the "identity" section, each student had their own page (called a "view" on the Knowledge Forum) where they could write weekly reflective diaries about their identities (Figure 2). As these were public, students were asked to deepen each others ideas about themselves using a set of person-centered scaffolds, such as "From what you wrote, I now understand about you that...". Whether face-to-face or online, the person-centered principles of actively and empathically listening to others, giving unconditional positive regard, and being congruent or real in relationships were emphasized throughout and modelled by the moderators (Rogers, 1969). Together, the combination of the idea- and person-centered activities formed the HKBC model.

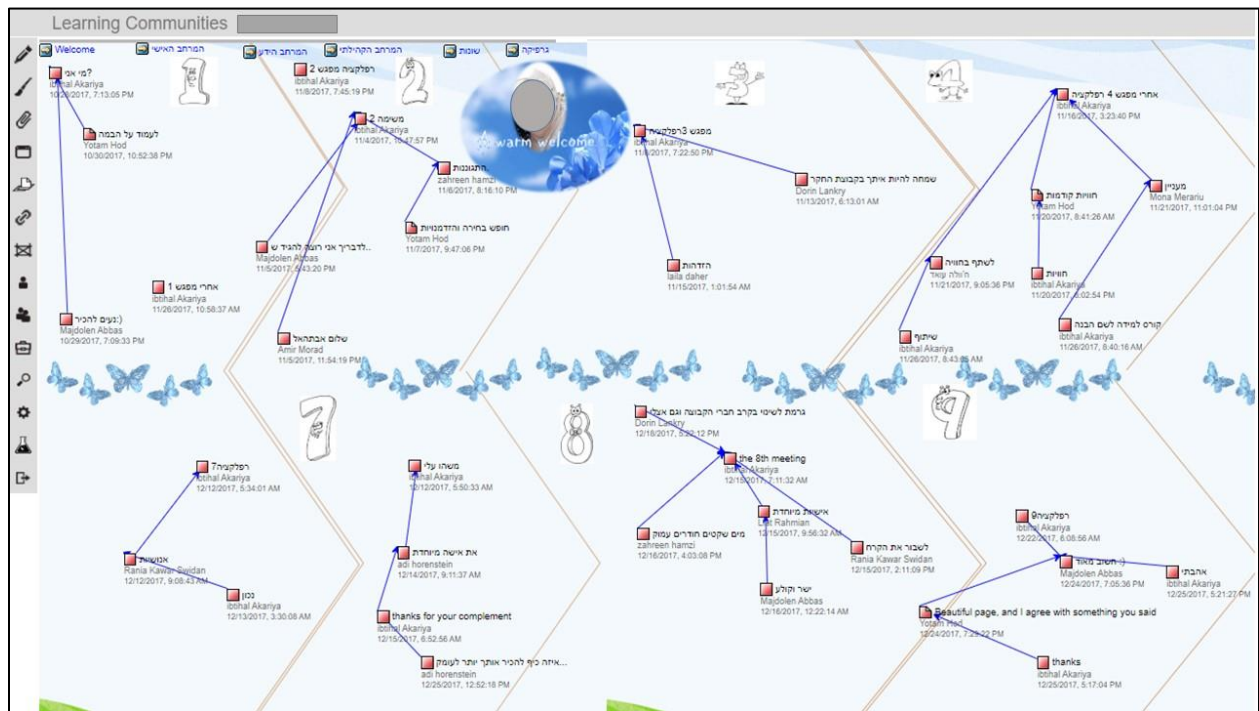


Figure 2. A personal page of a student with interpersonal discussions on the Knowledge Forum, repurposed for identity-building discourse

While this research focuses on the person-centered aspect of the HKBCs development, both aspects of the HKBC were interrelated. Many of the socioemotional expressions in the "identity" section of the KF referenced participants' reactions to the challenges of taking high levels of epistemic agency or collective cognitive responsibility. Likewise, the communities' knowledge building efforts were shaped by their developing group cohesion and the broader dimensions of their interpersonal relations (Authors, 2020). The co-moderators' approach for both aspects of the course, to support knowledge building and socioemotional developments, entailed

continually attending to, interpreting, and acting on (Sherin, Jacobs, & Philipp, 2011) what they understood to have emerged based on knowledge building and person-centered principles (Cornelius-White & Harbaugh, 2010; Zhang et al., 2011).

2.2 Data Collection and Analysis Methods

This study involved re-analyzing data that was used to create a qualitative analysis in a previous study (Authors, 2020). Section 2.2.1 describes the qualitative ethnography that was previously conducted (and refined for the current study) to establish the grounds for the current ENA that is described in section 2.2.2.

2.2.1 Qualitative Analysis from Previous Study

The first analysis involved employing a grounded analysis of all the notes on the Knowledge Forum to track the participants' socioemotional expressions throughout the semester. These were particularly found in the "identity" section of the Knowledge Forum, as described in section 2.1. In total, we found six categories (desire, dynamics, feelings, life outside, empathy, and likeness) based on the analysis of 1,170 collected notes (Table 2). Many notes were assigned multiple codes, for a total of 1,884 coded lines. The results from an interrater reliability check (performed specifically for the current study) were based on two raters examining 30 percent of the total number of coded expressions. Cohen's Kappa coefficients for the agreement between the two raters was .85 for the categories and .82 for the levels.

Table 2. Socioemotional dimensions with examples

Category Name	Sub-category with description (number of instances)	Example
Desire: Desire to work together as a community (desire)	Unelaborated and with some hesitations: Unelaborated expression to participate in the community and/or an expression with a desire but with some hesitation or conditions to be a part of the community (49)	"The session helped me get to know the community members better and ... made me feel more at ease and more willing to share... In the first week, I wrote notes, but minimally."
	Elaborated without (or little) hesitations and/or taking interpersonal initiative: Direct elaborated expression to participate in the community and/or making some interpersonal effort or initiative to support a member of the community in their participation (122)	"I agree that responsibility for cooperation in the forum should be taken. I felt a lot of help from others... I sincerely hope that I also contributed to them and hope for fruitful cooperation..."
	Elaborative and reflective with no hesitations and/or taking community-level initiative: Elaborated with a personally meaningful reflection that expresses some special significance and/or making some community level effort or initiative to bring the community together (45)	"A week ago we talked about responsibility and here I am taking it on... Every week from now on I will choose a few members of our community and pull out information from their page and you have to guess who that person is. I am inviting everyone to participate in this challenge."
Dynamics: Sharing thoughts in relation to underlying	Safe, unelaborated: Expressions reporting on the interpersonal interactions or the group dynamics that touch on some underlying issue without directly elaborating on it. (89)	"The previous meeting provided a good basis to continue the interesting discussion that developed in the last meeting. I felt that the people who are typically quiet shared their feelings authentically..."

issues about personal interactions or the group's dynamics	<p>Indirect, elaborated: Expressions in relation to interpersonal interactions or the group dynamics with some explanation or interpretation about the underlying issues for why they may be happening (133)</p> <p>Direct, elaborated: Direct expressions addressing underlying issues or challenges in the community in relation to the what is going on interpersonally in the community or to the group dynamics (141)</p>	<p>"I am really happy with myself because I participated in the community and I am going through a process and learning about myself... I also did not talk much. It shows that this is about character and not to the course itself, and yes, the assignments connected and brought us together and we learned about one another. I appreciate your words very much... I wanted to say there is a drop in forum activities and even if I don't respond to people, they anyway don't respond themselves. It was an interesting day and interesting things came up that I had to say."</p> <p>"I think there are loads of masks between us. I think last year's intensity brought this community out of balance, perhaps because there wasn't a balance in the first place. At the beginning of the semester, statements were made like 'this community is very supportive and united because we knew each other last year.' I think that statements of this kind have not proven themselves..."</p>
Feelings: Reflecting on personal or private feelings about a person's participation or feelings within the community	<p>Safe, personal revelation: Sharing of relatively trivial or abstract things about a person's feelings within the community (23)</p> <p>Unelaborated revelations: Expressions that are generally held privately about a person's feelings within the community. (39)</p> <p>Elaborated and reflective personal revelations: Expressions of feelings that have a special, meaningful, and personal nature relating to a person's feelings in the community (86)</p>	<p>"Who am I as a member in the learning community? I am the person that gives a different perspective that believes in dialogue between different people..."</p> <p>"In the past I had many experiences doing work in groups, unfortunately I am still not connecting to the topic of this current course, the different discussions repeat themselves, and the silence that is being created is unproductive."</p> <p>"I felt how difficult it was to not have control, even with the smallest or the most central aspects of our lives (like drawing someone). I was scared because I thought that Nina, who is sitting across from me, had expectations that I would draw her exactly the way that I think she looks and any error or exaggeration in the drawing would be interpreted badly."</p>
Life outside: Sharing or reflecting about a person's personal life outside the community	<p>Unelaborated and impersonal: Sharing of details about a person's life outside the community that are generally insignificant or, if there is something significant, it is unelaborated. (36)</p> <p>Elaborated and personal: Disclosing significant details about a person's life outside the community and elaborating on them. (70)</p> <p>Elaborated, personal, and reflective: Disclosing significant details about a person's life, elaborating on them, and reflecting on how this relates to their identity. (69)</p>	<p>"I am from [location], married and mother of a sweet 3-year-old child, I am the eldest daughter in the house and we are three sisters with no brothers, we have an amazing father and mother..."</p> <p>"I am known as a person who hates closed spaces; it just brings out very negative emotions in me... The moderator did not give up on me, called me, supported me... it just warned my heart."</p> <p>"During the meeting, I felt how much I am being heard and that my contribution to the community is significant. To be honest, a lot of thoughts come up during the sessions, and every opinion that is stated brings up questions in me and different analogies that I look for answers to... It is difficult to change a person's nature, and it is difficult for me to change. Once my supervisor told me: 'Your silence is soothing. Don't change. Stay calm. It reflects on others and soothes them.' I believe that life does not</p>

need recklessness and that you shouldn't judge people quickly.”

Empathy: Expressions of empathy towards others (and/or "seeing" each other)	Unelaborated acknowledgement: Acknowledgements of someone else's feelings or referring to someone else's emotions. (65)	“No matter how much you work and get to know a person, there will always be something to learn if you delve deeper into the relationship. I love this assignment of getting to reveal the whole you, and I'm glad you love it too. Thanks so much for the mutual wish :)))”
	Elaborated acknowledgement: Acknowledgements of someone else's feelings with some explanation about why they are being acknowledged. (182)	“I don't know where to start... Although we know each other very well, I would love to see, read and acknowledge this special note [that you wrote]. Know that you are a wonderful mother, to a perfect son, [a person] who knows how to combine between your career and motherhood...”
	Elaborated acknowledgement with a broader interpretation: Acknowledgements of someone else's feelings with an interpretation about its meaning in relation to the person or community. (210)	“After the last meeting, I saw you and I felt something special in your words, and I understood you right away. Good for you for the courage on the long way you have come, not all women can do this after such a long time... You are right, it is really hard to connect to people easily, and not everyone has the same type of character... I think we have a nice opportunity in this community that allows us to get to know people and talk to them, and slowly let the relationship develop. I hope you can get closer to others and develop relationships so they are your good friends...”
Likeness: Likeness and caring towards participants and/or the community	Unelaborated: Short, clichéd, and/or laconic expression of likeness and caring towards the community and/or participants in it. (128)	“I believe in you.”
	Elaborated: Expression that includes an explanation or demonstrates specific and situated knowledge of the recipient with likeness and caring towards the community and/or participants in it. (80)	“I really like to listen to what you say... In the community meetings I feel like you are an active community member and I think that you advance what is happening within our community...”
	Elaborated and reflective: Expression along with a personal reflection (of the author) of likeness and caring towards the community and/or participants in it. (73)	“It was really hard for me at first, but after my conversation with you, something within me was released, from being judgmental and critical. There was some change to acceptance and understanding, and I really don't take this for granted.”

The second aspect of this study involved analysing the way the community advanced socioemotionally by looking through a group development framework. Although there are overlaps between stages and frequent regressions, the general themes were evident through an analysis of field notes from face-to-face meetings and the socioemotional postings on the Knowledge Forum. The stages are summarized (Table 3) based on the timeframe they occurred, with key events from face-to-face meetings indicated along with illustrative examples.

Table 3. Key Events and Timeframe for each Stage of Learning Community Development

Stage	Weeks	Key Events
Initial	1 to 3	Group talked about being a "learning community" but their behavior was not consistent with this. For example, the first activity required some level of voluntary personal disclosure. Several students did not participate. There was a great deal of polite, but laconic talk, such as students wishing each other well.
Transition	3 to 6	In addition to questioning why the group should reflect on their own process of learning together, two group silences took place, each approximately two minutes long. Students showed a great deal of discomfort, particularly when asked to talk about interpersonal issues. For example, when one of the moderators talked about the possible meanings of group silences in response, one of the students jumped out of their chair and claimed that it was very hot in the room.
Working	6 to 11	The group began to explore and mend some of the issues that had risen. One of the main fissures had to do with some interpersonal conflicts that arose between some students in the year before that remained as "unfinished business". As the students began working through these conflicts and developing newfound trust and cohesion, one of the students burst out crying, saying how thankful she was to have had the group's support. Many other students made meaningful personal disclosures.
Final	11 to 13	The group made newfound efforts to use the remaining time they had meaningfully, such as by self-organizing a catered lunch, organizing a "get to know you" game during the last meeting, and putting together a Facebook group so they could stay in touch after the course ended.

2.2.2 Epistemic Network Analysis

Drawing on the analyzed data set from Authors (2020), we applied ENA using the ENA Web Tool v1.6.0 (Marquart, Hinojosa, Swiecki, Eagan, & Shaffer, 2018). We defined the units of analysis as a single note indexed by the day it was written and corresponding stage of group development, who authored it, which socioemotional codes were applied to it, and how many people read that note.

The ENA algorithm uses a moving window to construct a network model for each line in the data, showing how codes in one note are connected to notes that occur within the group developmental stage (Siebert-Evenstone et al., 2017), defined as four notes (each note plus the three previous notes). The resulting networks are aggregated for all lines for each unit of analysis in the model. In this model, we aggregated networks using a weighted summation in which the networks for a given note reflect the log of the product of each pair of codes. Our ENA model included one code for each socioemotional category. We defined conversations as all notes within a stage.

The ENA model normalized the networks for all units of analysis before they were subjected to a dimensional reduction, which accounts for the fact that different units of analysis may have different amounts of coded lines in the data. For the dimensional reduction, we used a singular value decomposition, which produces orthogonal dimensions that maximize the variance explained by each dimension (Shaffer et al., 2016).

Networks were visualized using network graphs where nodes correspond to the codes, and edges reflect the relative frequency of co-occurrence, or connection, between two codes. This results in two coordinated representations for each unit of analysis: (1) a plotted point, which represents the location of that unit's network in the low-dimensional projected space, and (2) a weighted network graph. The positions of the network graph nodes are fixed, and those positions are determined by an optimization routine that minimizes the difference between the plotted points and their corresponding network centroids. Because of the co-registration of network graphs and projected space, the positions of the network graph nodes – and the connections they define – can be used to interpret the dimensions of the projected space and explain the positions of plotted points in the space. Our model had co-registration correlations of 0.8 (Pearson) and 0.8 (Spearman) for the first dimension and co-registration correlations of 0.95 (Pearson) and 0.96 (Spearman) for the second.

3. Results

The following subsections (3.1, 3.2) show the results of the ENA based on the existing qualitative ethnography.

3.1 ENA of Socioemotional Developments

The ENA showed that the stages of group development could be discriminated robustly based on the socioemotional coding (Figure 3, Table 4). These results and interpretations did not differ when we ran the ENA using different window sizes (4-12), aligning with Ruis et al.'s (2019) finding that ENA results are stable across changes to window size.

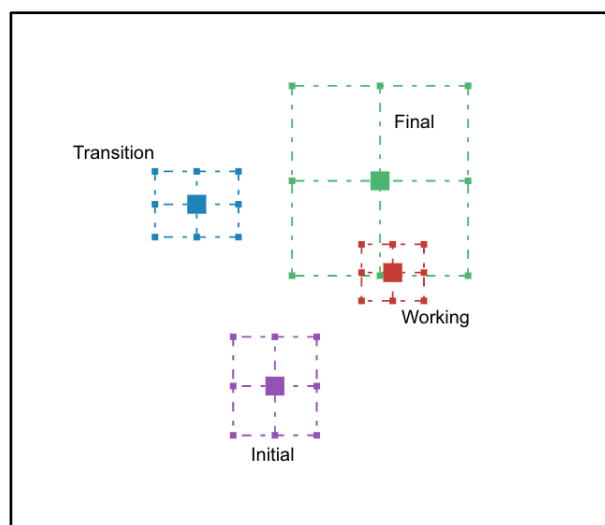


Figure 3. Mean of the plotted points for each developmental stage

The x-axis in our ENA space defined the socioemotional dimension as having the life outside category on the left (lower x values) and dynamics, empathy, and likeness on the right

(higher x-values). This means that stages or units further to the left made more connections to the socioemotional category life outside; stages or units further to the right have more connections to and between the socioemotional categories of dynamics, empathy, and likeness. The y-axis in our ENA space defined the socioemotional dimension with dynamics and feelings higher up in the space (higher y values) and desire, life outside, and empathy as lower in the space (lower y values). This means stages higher in the space made more connections to and between the socioemotional codes dynamics and feelings. Stages further down in the space had more connections to and between desire, life outside, and empathy.

Table 4. Summary of Mann-Whitney comparisons

Title	Axis	Median(N)*	Median(N)**	U	P-value	R (effect size)
Initial vs. Transition	x	-0.08 (100)	-0.41(115)	4526.00	0.01	0.21
	y	-0.27 (100)	-0.04(115)	3082.00	0.00	0.46
Initial vs. Working	x	-0.08 (100)	0.26 (230)	15141.00	0.00	-0.32
	y	-0.27 (100)	-0.04(230)	8101.00	0.00	0.30
Initial vs. Final	x	-0.08 (100)	0.18(29)	1865.50	0.02	-0.29
	y	-0.27 (100)	0.17(29)	782.50	0.00	0.46
Transition vs. Working	x	-0.41(115)	0.26 (230)	19081.00	0.00	-0.44
	y	-0.04(115)	-0.04(230)	15808.50	0.00	-0.20
Transition vs. Final	x	-0.41(115)	0.18(29)	2485.00	0.00	-0.49

*For the first stage in the comparison

**For the second stage in the comparison

We note that there were no statistically significant differences between the transition versus final stage on the y-axis and working versus final stage on either the x or y axis, and therefore we left them out. We further note that the overlap between the working versus final stage was expected, as during the final stage a group can still be characterized as working (in that they are disclosing, discussing emotions, actively listening, etc.). The key difference is the relation to questions about the end of the group and not the socioemotional process by which groups function. The initial and transition stage are different in that the disclosure and empathy either occur at shallow levels, or not at all.

3.2. Elucidating Qualitative Ethnographies using ENA

Following the calculation of our results, we applied the quantitative measures to elucidate several phenomena found in the qualitative ethnography. We focus on two illustrative examples in sections 3.2.1 and 3.2.2.

3.2.1 Recognizing the Importance of Prior Experience

The ENA from notes coded during the initial stage revealed a strong and unanticipated connection between expressions showing the desire to work together as a community and those of empathy towards others (Figure 4). The desire to work together as a community was expected to be at a high level during this stage, as it is indicative of the general optimism and excitement of newly formed groups. Even though most of the students knew each other from their first year of studies together, this was the start of a new semester that was separated by a summer break. Therefore, sentiments along the lines of Paige's expression that "everyone here loves everyone else" were common at the start.

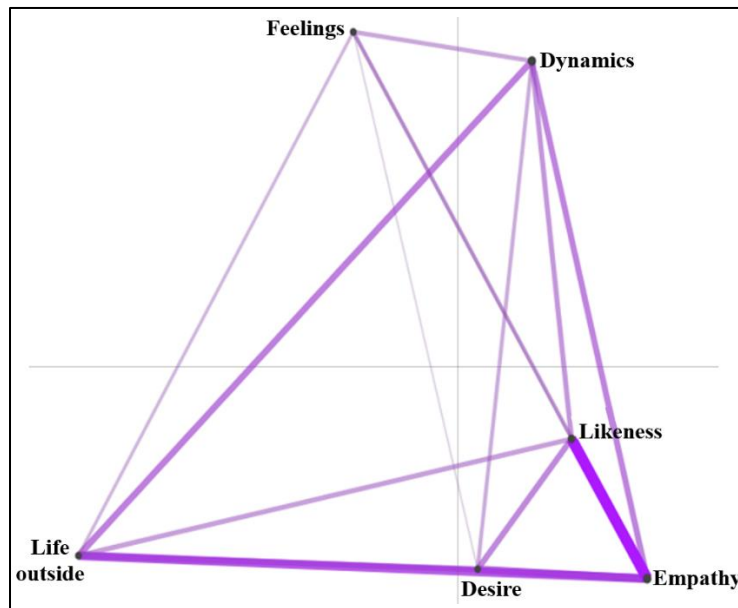


Figure 4. Socioemotional network graph of initial stage

At the same time, the group had a history and most of the students were familiar with one another. Their shared experiences provided them with historical resources that facilitated their ability to understand and empathize with one another more than a newly formed group would. For example, in the following exchange, Sara wrote a reflective post during the second week on the Knowledge Forum where she reflected on some of her practices from the previous week:

Sara: During the first assignment I tried very hard to answer the questions in a focused way. This is something that characterizes me. In addition, I carefully chose the words that I used, words that I was comfortable sharing with all the members of the community. I chose to respond to one person in the community who I do not know so well, and another person who I know well from last year. It takes me a while to get used to the learning community, trust it, and open up to new people.

In response, Leyla wrote a note that combined both her desire for the community to work together and empathy in a very specific response to Sara based on her knowledge from their past experience together:

Leyla: For me personally it was very pleasant to work with you in the group [last year]. Last year I saw you as silent but observing all the time, but I think that you can contribute a lot more to our learning community if you shared more.

Leyla's desire for Sara to take a more significant part in the community was clearly influenced by their past experience together and Leyla's ability to empathize with Sara's situation. Consequently, the response to Sara was customized to her, particularly encouraging Sara to overcome a perceived weakness that Leyla assessed about Sara. Her expressed desire for the community to work together was therefore influenced by the empathy she developed from their first year together.

In contrast to this, Margaret was one of the new students in the group, whose only previous relation was with Tanya. Margaret's reflective diary entry during the second week explicitly noted her lack of interpersonal relations, which showed the general way that she expressed her desire for the community to work together:

Margaret: The notes gave me the feeling that there is a disconnected conversation. There are no immediate responses to what we are saying. Because the notes were in people's personal pages, this made me feel required to answer to everyone who wrote to me, even if there wasn't a real need. It is as if it won't be polite to leave something without responding to it. I assume that as the community will develop, and the writing will become stronger, also in our knowledge space, it will be easier to answer when I have something to contribute and not because it is important for me to answer everyone.

To sum, the desire to work together is a common feature of initial stages, but because people generally do not know one another they cannot draw on their experiences and respond in customized or nuanced ways. Given the background of this particular group, their knowledge of one another helped them, to some extent, give customized encouragement that actually dealt with the particular challenges that people faced. Therefore, the connection between the categories that the ENA found is likely more specific to the initial stage in our context in comparison to the initial stage in contexts where groups have limited or no experiences together.

3.2.2 A Changing Focus on Group Dynamics from Difficulty to Empathy

One of the strong connections that was unique in the transition stage was that between discussion of the community and interpersonal dynamics with people sharing personal or private feelings about their participation in the community (Figure 5).

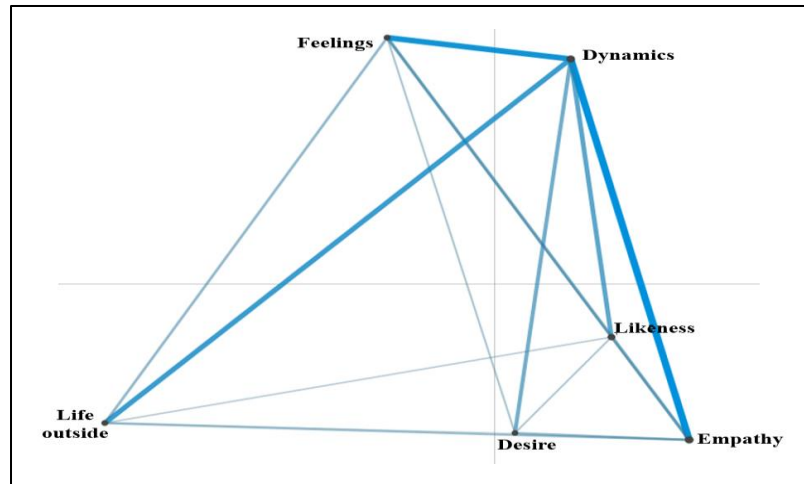


Figure 5. Socioemotional network graph of transition stage

On the whole, at this stage, these personal feelings were negative, touching on issues of frustration, confusion, and embarrassment. We note that these occurred to a great extent around and in reaction to the episodes of silence during week four.

Zed: I don't feel so comfortable with the silence... The purpose of the process is not clear to me yet and therefore it is hard for me to put myself inside of it.

Sara: For some parts of today I felt less comfortable... I felt embarrassed... I feel like the environment isn't natural.

Nina: I want to address the matter of the silence that took place. As you noticed, it is very hard for me to deal with embarrassing silences. Therefore, I broke the silence and immediately I felt uncomfortable... When there is silence I lost interest, and I start moving in my chair and in particular in chairs where there are wheels.

Tanya: The activity from the last meeting and specifically the discussion around the silence were frustrating for me... Simply because I had a feeling that nothing was moving anywhere.

It is interesting to compare this with the working stage, where again the group is highly focused on their dynamics, however this time the connection with empathy becomes the central socioemotional axis of the participants' discourse (Figure 6).

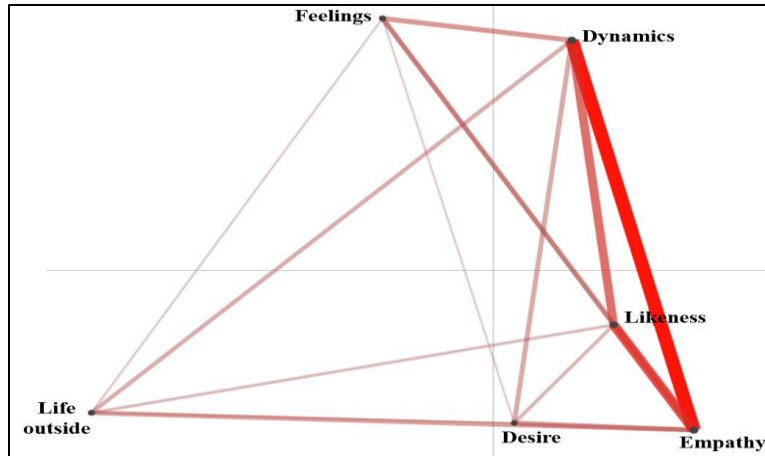


Figure 6. Socioemotional network graph of working stage

For example, during the eighth week, Azeer wrote a post in the context of an intense conversation where the group was discussing the individual role of each of the community participants. Azeer had been a relatively quiet member who felt that she needed to defend her position in the community:

Azeer: Over the past two weeks the discussion has mostly revolved around those who speak less and share, and I happen to be in this respectable group. I understand and respect what has come up... but the fact that one chooses not to speak or disagree most of the time certainly does not make me a less appreciated or less significant member of the group... That is my character! You can't force a person to speak. Through my silence I learn something about you, and it doesn't mean I have no commitment to the group or to myself because I don't talk much.

In response, Sara posted a note that showed a great deal of empathy by accepting Azeer's silence without judgement, but also using her ability to understand her point of view and extend the idea.

Sara: I "hear" what you are saying, that you think the discussion during recent meetings has revolved around the "quiet" people in our community. I don't think the intention was to argue that being quiet means being less meaningful to the community... [Rather,] it was about commitment and responsibility... which can be expressed in a variety of ways, not just through talk during face-to-face meetings. This can be reflected in contributing to the inquiry groups, or making in-depth conversations with new people in the community, or the ability to address issues that are less convenient for us to hear. As Theresa wrote, the essential thing is to know for yourself the source and reasons for how much you choose to participate in the various activities of the community. I think you did that. You wrote that you prefer to watch, learn from other things and that this is part of your character and I totally respect that.

In both the transition and working stages, the group dynamics were a focal aspect of the community's conversation. However, in the transition stage the group tied their dynamics to the difficulties and challenges that they were having; during the working stage, the conversation

around the dynamics shifted to understanding one another and showing empathy. This development seems reasonable. Before members of a group can empathize with one another, they first need to share their honest thoughts about what may be difficult or challenging. As long noted in literature on group dynamics, at first these are typically expressed outwards while casting some blame, and over time the personal responsibility that people have can be reflected on and better understood (Rogers, 1970). The ENA of the socioemotional coding over the stages of group development was successful in showing this change, refining it to show how talk of the dynamics is constant, but privileges connections with different socioemotional ideas at different stages.

4. Discussion

The aim of this research was to elucidate how digital technologies, and particularly ENA, could be used to understand and support the socioemotional development of classroom learning communities. To do this, we re-analyzed qualitative data collected about the socioemotional expressions by course participants. The qualitative data included six categories (each with three sub-levels) that characterized the type of socioemotional functioning the community had, as well as the identification of four group developmental stages. We brought the categories and stages together through an ENA which both confirmed that the stages were statistically discrete, and to see what kind of insights about the socioemotional functioning of learning communities this could yield by looking across the categories and stages.

4.1. Theoretical Implications

Sections 3.3.1 and 3.3.2 of the results elaborate on ways that the quantitative ethnographic approach of ENA could illuminate aspects of the qualitative ethnography that we carried out through coding and stage analysis. In particular, it showed the importance of prior experience and how this interacts with participants' connectedness to the community. It also showed how group dynamics are a vital aspect of community discourse and that the socioemotional dimensions that people attach to it may be the determinants of stage advancement. As this study is ethnographic in its nature, we do not seek to generalize these points, but to see what we can learn about how we think about the socioemotional nature of classroom learning communities as well as how ENA can be used to understand complex human-centered phenomena.

With regards to the first point about better understanding the socioemotional nature of classroom communities, we are able to see how different facets of socioemotional functioning are related to one another and how these evolve over time. For example, in our case, empathy was important in the initial stage in keeping people feeling connected based on the prior experience that they had together. Lacking this experience and empathy, students may have felt disconnected and less interested in being a part of the group. Thus, it appears that in addition to characterizing the initial stage in terms of its defining characteristics of excitement, low risk-taking, and lack of self-direction (Arrow et al., 2004; Corey et al., 2018), it can be characterized as a set of relations between different socioemotional characteristics. In so far that these relations may be more parsimonious than the well-known definitions, in certain circumstances they may be a preferred conceptualization. More research is needed in this area; this study provides a framework whereby these relations can be developed.

This research takes an ecological perspective of learning environments, recognizing that what emerges does so through the co-construction of interactions that is facilitated by designed activities, technologies, and spaces (Damşa, Derland, & Andreadakis, 2019). A central challenge of research looking at socioemotional ecologies involves untangling these complex interactions

(Baker, Andriessen, & Järvelä, 2014). By applying ENA in this study, we have been able to observe fine-grained changes to interdependent phenomena as they develop over time (Shaffer, 2018). Specifically, the network graphs (Figures 4, 5, and 6) represent different arrangements in specified periods of time that have been explored in scholarship on groups for over half a century (Arrow et al., 2004; Brabender, 2020). This research shows how computer models can be used to discover new aspects of these illusive, but vital and robust phenomena in educational settings.

More generally than this, ENA can be used to understand the complex phenomena in communities by combining it with deep, qualitative ethnographies. One of the points that stands out from this study is the way the quantitative analysis informed the qualitative one and vice versa. Doing this required deep knowledge of the functioning of the community both in the form of decontextualized grounded coding as well as contextualized analysis based on a group stages framework. Previous research in ENA, and learning analytics focused on socioemotional dimensions, have rarely taken such a contextual approach (Authors, 2019; Frey et al., 2019). Had we only coded the socioemotional dimension without the stages, it would have been very difficult to make meaning of the changing socioemotional connections. The qualitative ethnography provided us with a canvas on which we could make meaning out of the complex phenomena. The ENA helped us refine the story that we observed by elucidating new interactions, instead of seeking to take its place.

4.2 Limitations and Next Steps

The limitations of this study were its focus on one particular context. Currently, carrying out deep qualitative ethnographies is very time consuming and, for the most part, can only be completed retrospectively. One of the promises of computers and education is the ability to help the instructors and students become more intentional in their activities. For this to happen in a context such as ours, we would need to, first, automate the assessment of online talk so that it can identify categories of socioemotional dimensions. There are promising directions in the automated analysis of online talk that can be helpful (Paulus & Wise, 2019). Second, this would entail collecting data on a number of groups such as the one we have studied in this ethnography to see if we can find socioemotional coding patterns across contexts. If both of these steps can be achieved, then instructors and students can have automated tools that can help them regulate their own functioning and ultimately better support the development of their classroom learning communities.

5. Conclusion

Contemporary educational research has increasingly pointed to the interrelatedness of socioemotional and sociocognitive dimensions of learning (Allen, Vella-Brodrick, & Waters, 2017). Learning analytics, and particularly ENA, has the promise of representing socioemotional dimensions of learning in different ways than traditional conceptualizations have. At this point in the development of emotional learning analytics, it is vital to carefully examine qualitative and quantitative interpretations together to better understand how they are complementary and in what situations one representation is more ideal than the other. Research and development in this area is needed. This study is the first time that ENA has been applied to a qualitative ethnography of socioemotional dimensions of learning communities, leading to some new insights and challenges that future research in the area can build on.

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References

- Allen, K., Vella-Brodrick, D., & Waters, L. (2017). School belonging and the role of social and emotional competencies in fostering an adolescent's sense of connectedness to their school. In E. Frydenberg, A. J. Martin, & R. J. Collie (Eds.). *Social and emotional learning in Australia and the Asia-Pacific* (pp. 83-99). Singapore: Springer.
- Arrow, H., Poole, M., Henry, K., Wheelan, S. & Moreland, R. (2004). Time, change and development: Temporal perspective on groups. *Small Group Research*, 35(1), 73-105.
- Authors (2015; 2018a; 2018b; 2019; 2020)
- Baker, B., Andriessen, M. & Järvelä, J. (Eds.) (2014). *Affective Learning Together: Social and Emotional Dimensions of Collaborative Learning*. Routledge.
- Barron, B. (2003). When smart groups fail. *The Journal of the Learning Sciences*, 12(3), 307-359.
- Bielaczyc, K. (2009). Designing social infrastructure: Critical issues in creating learning environments with technology. *Journal of the Learning Sciences*, 15(3), 301-329.
- Bielaczyc, K., & Collins, A. (1999). Learning communities in classrooms: A reconceptualization of educational practice. In C. M. Reigeluth (Ed.), *Instructional design theories and models: A new paradigm of instructional theory* (pp. 269-292). Mahwah, NJ: Lawrence Erlbaum Associates.
- Bielaczyc, K., Kapur, M., & Collins, A. (2013). Cultivating a community of learners in K-12 classrooms. In C. E. Hmelo-Silver, C. A. Chinn, C. K. Chan, & A. M. O'Donnell (Eds.), *International handbook of collaborative learning* (pp. 233-249), New York, NY: Routledge.
- Bion, W. (1959). *Experiences in Groups*. London, UK: Tavistock Publications.
- Brabender, V. (2010). Group development. In R. K. Conyne (Ed.), *Oxford handbook of group counseling* (pp. 182-204). Oxford, UK: Oxford University Press.
- Carabajal, K., LaPointe, D., & Gunawardena, C. N. (2003). Group development in online learning communities. In M. G. Moore, & W. G. Anderson (Eds.), *Handbook of distance education* (pp. 217-234). Mahwah, NJ: Lawrence Erlbaum Associates.
- Chen, B., & Hong, H. Y. (2016). Schools as knowledge-building organizations: Thirty years of design research. *Educational Psychologist*, 51(2), 266-288.
- Collins, A. (2017). *What's Worth Teaching? Rethinking Curriculum in the Age of Technology*. New York, NY: Teachers College Press.
- Corey, M. S., Corey, G., & Corey, C (2018). *Groups: process and practice* (10th Ed.). Belmont, CA: Brooks/Cole Publishing Company.
- Cornelius-White, J. H., & Harbaugh, A. P. (2010). *Learner-centered instruction: Building relationships for student success*. Los Angeles, CA: Sage publications.
- Cress, U., Rosé, C. P., Law, N., Ludvigsen, S. (2019). Investigating the complexity of computer-supported collaborative learning in action. *International Journal of Computer-Supported Collaborative Learning*, 14(2), 137-142.

- Damşa, C., Nerland, M., & Andreadakis, Z. E. (2019). An ecological perspective on learner-constructed learning spaces. *British Journal of Educational Technology*, 50(5), 2075-2089.
- D'Mello (2017). Emotional learning analytics. In C. Lang G. Siemens, A. Wise, & D. Gasevic (Eds.). *Handbook of learning analytics* (pp.115-127). SOLAR, Society for Learning Analytics and Research.
- Frey, K. S., Kwak-Tanquay, S., Nguyen, H. A., Onyewuenyi, A. C., Strong, Z. H., & Waller, I. A. (2019). Adolescents' Views of Third-Party Vengeful and Reparative Actions. In *International Conference on Quantitative Ethnography* (pp. 89-105). Springer, Cham.
- Järvelä, S., Kirschner, P. A., Hadwin, A., Järvenoja, H., Malmberg, J., Miller, M., & Laru, J. (2016). Socially shared regulation of learning in CSCL: Understanding and prompting individual-and group-level shared regulatory activities. *International Journal of Computer-Supported Collaborative Learning*, 11(3), 263-280.
- Järvenoja, H., & Järvelä, S. (2013). Regulating emotions together. In M. Baker, J. Andriessen, & S. Järvelä (Eds.), *Affective learning together. Social and emotional dimensions of collaborative learning* (pp. 162-182). New York, NY: Routledge.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.
- Lewin, K. (1952). *Field theory in social science: Selected theoretical papers by Kurt Lewin*. London: Tavistock.
- Marquart, C. L., Hinojosa, C., Swiecki, Z., Eagan, B., & Shaffer, D. W. (2018). *Epistemic Network Analysis (Version 1.6.0) [Software]*. Available from <http://app.epistemicnetwork.org>
- Matthews, R. S., Smith, B. L., & MacGregor, J. (2012). The evolution of learning communities: A retrospective. *New Directions for Teaching and Learning*, 2012(132), 99-111.
- McInnerney, J. M., & Roberts, T. S. (2004). Online learning: Social interaction and the creation of a sense of community. *Educational Technology & Society*, 7(3), 73-81.
- Miller, D. L. (2003). The stages of group development: A retrospective study of dynamic team processes. *Canadian Journal of Administrative Sciences*, 20(2), 121-134.
- Miyake, N., & Kirschner, P. A. (2014). The social and interactive dimensions of collaborative learning. In K. R. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 418-438). New York, NY: Cambridge University Press.
- Näykki, P., Järvelä, S., Kirschner, P. A., & Järvenoja, H. (2014). Socio-emotional conflict in collaborative learning—A process-oriented case study in a higher education context. *International Journal of Educational Research*, 68, 1-14.
- Paulus, T. M., & Wise, A. F. (2019). *Looking for insight, transformation, and learning in online talk*. New York, NY: Routledge.
- Rogers, C. R. (1969). *Freedom to Learn*. Columbus, OH: Charles Merrill Publishing Company.
- Rogers, C. R. (1970). *Carl Rogers on encounter groups*. New York, NY: Harper & Row Publishers.
- Rogoff, B. (1994). Developing understanding of the idea of communities of learners. *Mind, culture, and activity*, 1(4), 209-229.
- Ruis, A. R., Siebert-Evenstone, A. L., Pozen, R., Eagan, B., & Shaffer, D. W. (2019). Finding common ground: A method for measuring recent temporal context in analyses of complex, collaborative thinking. In K. Lund, G. Niccolai, E. Lavoué, C. Hmelo-Silver, G. Gwon, & M. Baker (Eds.) *A Wide Lens: Combining Embodied, Enactive, Extended, and Embedded Learning in Collaborative Settings: 13th International Conference on Computer Supported Collaborative Learning*, (pp.136-143). Lyon, France: ISLS.

- Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67–98). Chicago IL: Open Court.
- Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences, Second Edition* (pp. 397–417). New York, NY: Cambridge University Press.
- Sherin, M., Jacobs, V., & Philipp, R. (Eds.). (2011). *Mathematics teacher noticing: Seeing through teachers' eyes*. Routledge.
- Shaffer, D. W. (2017). *Quantitative ethnography*. Madison, WI: Cathcart Press.
- Shaffer, D. W. (2018). Epistemic network analysis: Understanding learning by using big data for thick description. In F. Fischer, S. R. Goldman, C. E. Hmelo-Silver, & P. Reimann (Eds.), *International Handbook of the Learning Sciences* (pp. 520–531). New York, NY: Routledge.
- Shaffer, D. W., Collier, W., & Ruis, A. R. (2016). A tutorial on epistemic network analysis: Analyzing the structure of connections in cognitive, social, and interaction data. *Journal of Learning Analytics*, 3(3), 9–45.
- Shaffer, D. W., & Ruis, A. R. (2017). Epistemic network analysis: A worked example of theory-based learning analytics. In C. Lang, G. Siemens, A. F. Wise, & D. Gasevic (Eds.), *Handbook of learning analytics* (pp. 175–187). Society for Learning Analytics Research.
- Siebert-Evenstone, A., Arastoopour Irgens, G., Collier, W., Swiecki, Z., Ruis, A. R., & Williamson Shaffer, D. (2017). In search of conversational grain size: modelling semantic structure using moving stanza windows. *Journal of Learning Analytics*, 4(3), 123–139.
- Swiecki, Z. & Shaffer, D. W. (2020). iSENS: An integrated approach to combining epistemic and social network analyses. In *Proceedings of the 10th international conference on learning analytics and knowledge*. Frankfurt, Germany.
- Tinto, V. (2000). Learning better together: The impact of learning communities on student success in higher education. *Journal of Institutional Research*, 9(1), 48–53.
- Tosey, P., & Marshall, J. (2017). The demise of inquiry-based HRD programmes in the UK: Implications for the field. *Human Resource Development International*, 1-10.
- Tuckman, B. W., & Jensen, M. A. C. (1977). Stages of small-group development revisited. *Group & Organization Management*, 2(4), 419–427.
- Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.
- Weissberg, R. P., Durlak, J. A., Domitrovich, C. E., & Gullotta, T. P. (Eds.). (2015). Social and emotional learning: Past, present, and future. In J. A. Durlak, C. E. Domitrovich, R. P. Weissberg, & T. P. Gullotta (Eds.), *Handbook of social and emotional learning: Research and practice* (p. 3–19). The Guilford Press.
- Zhang, J., Hong, H. Y., Scardamalia, M., Teo, C. L., & Morley, E. A. (2011). Sustaining knowledge building as a principle-based innovation at an elementary school. *The Journal of the Learning Sciences*, 20(2), 262–307.
- Zhang, J., Scardamalia, M., Reeve, R., & Messina, R. (2009). Designs for collective cognitive responsibility in knowledge-building communities. *The Journal of the Learning Sciences*, 18(1), 7–44.
- Zhang, J., Tao, D., Chen, M. H., Sun, Y., Judson, D., & Naqvi, S. (2018). Co-organizing the collective journey of inquiry with idea thread mapper. *Journal of the Learning Sciences*, 27(3), 390–430.